

Increased Green Onion Yields Associated with Abamectin Treatments for *Liriomyza sativae* (Diptera: Agromyzidae) and *Thrips tabaci* (Thysanoptera: Thripidae)

MICHAEL K. KAWATE & JULIA A. COUGHLIN

University of Hawaii, Department of Environmental Biochemistry, 1800 East West Road,
Honolulu, Hawai'i 96822, USA

ABSTRACT. *Liriomyza sativae* is a major pest of green onions (*Allium cepa* L. var. "aggregatum") in the Waianae region of O'ahu, Hawai'i. Field trials were conducted for 2 seasons to evaluate abamectin for *L. sativae* control. Weekly applications of 0.02 kg abamectin/ha beginning 2 weeks after transplanting and continuing up to 7 d before harvest resulted in significant increases in marketable yield. In the first season, although counts of live leafminer larvae did not decrease in abamectin-treated onions, green onion yield increased 71%. In the second season, leafminer pupae were counted instead of leafminer larvae. Counts of leafminer pupae decreased in abamectin-treated onions and green onion yield increased by 40%. Abamectin was effective in controlling *L. sativae* in green onions with possibly little or no effect on parasitoids. Onion thrips (*Thrips tabaci*) injury in abamectin-treated plots was significantly lower than in untreated control plots.

INTRODUCTION

Production of green onions (*Allium cepa* L. var. "aggregatum") in Hawaii is concentrated in the Waianae region of Oahu. Green onions are planted year-round and harvested 10–12 weeks after planting. In 1991, there were approximately 85 ha in production statewide, yielding 8,518 kg/ha with a total value of \$1.6 million (Hawaii Agricultural Statistics Service 1991). The major insect pest of green onions in Waianae is the vegetable leafminer, *Liriomyza sativae* Blanchard (Diptera: Agromyzidae). *Liriomyza sativae* is the only agromyzid pest species found on green onions in this area (Carolina et al. 1992). *Liriomyza* larvae produce serpentine mines that reduce photosynthetic area and plant vigor, and directly damage the marketable foliage of green onions. When onions are harvested, growers must remove the damaged portions to meet grading standards. This process is extremely labor intensive and, when leafminer densities are high, growers experience severe losses.

Liriomyza leafminer populations are influenced naturally by a complex of hymenopterous parasitoids (Johnson & Hara 1987.) The parasitoid complex associated with *L. sativae* in green onions in Waianae is dominated by the eulophid parasitoid *Chrysoneotomyia punctiventris* (Crawford) (Herr 1987). However, this parasitoid is not capable of keeping *L. sativae* populations below economically damaging levels in green onion (Mothershead 1978). Insecticides applied to control *Liriomyza* spp. may be more toxic to parasitoids than to leafminers (Parrella 1987). Growers in Waianae have experienced severe losses resulting from leafminer damage despite frequent pesticide use. Insecticides, such as mevinphos and diazinon, applied as frequently as twice per week failed to suppress *Liriomyza* leafminers, especially in summer months when populations were highest (Herr 1987). Insecticide resistance is probably a contributing factor; development of resistance in *Liriomyza* spp. has been widely reported (Keil & Parrella 1982, Parrella & Keil 1984, Mason et al. 1987).

Abamectin (AVID 0.15 EC [2% emulsifiable concentrate], AGRI-MEK 0.15 EC; Merck & Co., Inc., Rahway, NJ) has been evaluated for leafminer control in several crops. In cantaloupe, abamectin reduced the number of *Liriomyza* leafmines per leaf (Royer &

Edelson 1989) and weekly applications of abamectin on tomato reduced pupal densities of *Liriomyza trifolii* (Burgess) (Carson et al. 1989). Hara (1986) found abamectin effective in controlling *L. trifolii* in potted and cut-flower chrysanthemums with no adverse effects on leafminer parasitoids. Parrella (1983) and Price (1983) found abamectin controlled *Liriomyza* strains that were resistant to commonly used insecticides. Abamectin does not affect the cholinergic system (Putter et al. 1981). The mode of action is different from other classes of pesticides and cross-resistance with several conventional pesticides was not observed in studies conducted by Roush & Wright (1986) and Hoy & Conley (1987). Abamectin penetrates the leaf surface (translaminar movement) leaving a persistent residue which is protected from degradation by direct sunlight (Wright et al. 1985, Schuster & Taylor 1987, Dybas et al. 1989). Leafminer larvae either ingest or come in contact with abamectin, however, abamectin was most effective when ingested (Putter et al. 1981). Surface residues dissipate rapidly (Iwata et al. 1985, Schuster & Taylor 1987) having little or no effect on leafminer parasitoids; this characteristic is desirable for integrated pest management programs.

Onion thrips is an important pest of green onions. Damage by thrips feeding results in silvering of the leaves. Severe thrips damage can reduce plant vigor and damage marketable foliage. Also, *T. tabaci* is a major pest of bulb onions. Edelson et al. (1989) determined that thrips control with cypermethrin and acephate significantly increased bulb onion yield and profit over untreated controls. Abamectin has been evaluated for thrips control on other crops. Nasruddin and Smitley (1991) found abamectin effective in reducing western flower thrips [*Frankliniella occidentalis* (Pergande)] injury in gloxinia. Abamectin effectively controlled orchid thrips [*Chaetanaphothrips orchidii* (Moulton)] in anthurium (Hara et al., 1988).

The objective of this study was to evaluate the efficacy of abamectin on *L. sativae* populations, to assess abamectin's impact on associated leafminer parasitoids, and to assess abamectin's effect on thrips damage in green onions.

MATERIALS AND METHODS

Efficacy trials were conducted in two separate plantings at commercial green onion farms in Waianae Valley, O'ahu, Hawai'i in 1989 and 1991.

1989 Season

Green onions were transplanted in raised beds on 11–12 July 1989. Each plot was 1.22 x 3.05 m. Within each raised bed, six rows of onions were spaced at 20.3 cm, and within each row, onions were spaced at 15.2 cm (i.e., 120 plants per plot or 32 plants per m²). Raised beds were 1.52 m apart. Treatments were arranged in a randomized complete block design with four replications. The field was sprinkler irrigated. Three treatments were established: 1) abamectin 0.01 kg (AI)/ha; 2) abamectin 0.02 kg (AI)/ha; and 3) untreated control. Sprays were initiated 2 weeks after transplanting and continued weekly for a total of nine applications. For the first 6 applications, abamectin was applied in 935 l of diluent/ha with 0.063% v/v Triton B-1956 spreader sticker (Rohm and Haas Co., Philadelphia, PA) in a CO₂-pressurized backpack sprayer at 207 kPa. A 3-nozzle boom with Teejet 8003XR flat fan nozzles (Spraying Systems Co., Wheaton, IL) was used. We determined that coverage and penetration were limiting factors for efficacy; hence, for subsequent applications, the diluent volume was increased to 1870 l/ha, the nozzles were changed to Twinjet 8006VS nozzles (Spraying Systems Co., Wheaton, IL), the surfactant was changed to Activator 90 (Loveland Industries Inc., Greeley, CO), the surfactant concentration was increased to 0.13% v/v, and the pressure was increased to 345 kPa.

Plots were sampled weekly, before spraying, for *L. sativae* larvae. Ten onion leaves were randomly selected from each plot. Leaves were taken to the laboratory, cut lengthwise, and examined under a dissecting microscope. Backlighting was used to illuminate the leafminer larvae within the mine. Numbers of live leafminer larvae and parasitized leafminer larvae were recorded for each leaf. Each plot was visually evaluated in the field for phytotoxicity on 2 and 9 August. A 0–100% injury scale was used.

Onion plots were harvested on 25–26 September. The onions were cleaned according to commercial practices; mined leaves and portions thereof were removed to meet the Hawai'i No. 1 standard, and fresh weights were recorded. Leafminer and parasite counts were analyzed on a weekly basis by analysis of variance with single df contrast comparisons (General Linear Models Procedure; SAS Institute 1988). Yield data were analyzed by analysis of variance with single df contrast comparisons (General Linear Models Procedure; SAS Institute 1988).

1991 season

Green onion plot dimensions, and within and between row plant spacings were the same as the 1989 season. Green onions were transplanted on 16 July 1991. The field was drip irrigated. Each plot was divided into 2 equal subplots, one caged and the other uncaged. Cage dimensions were 1.52 x 1.22 x 0.49 m. Frames of cages were constructed with 2.54 cm (ID) polyvinyl chloride (PVC) pipe, then fitted with white organdy fabric screening. Cages were placed on the subplots on 31 July. Onion plots were left exposed for 2 weeks to allow for leafminer oviposition before placing the cages on the subplots. Cages were removed from all subplots immediately before spray applications each week and replaced after all spraying was completed. The purpose of the caged subplots was to reduce leafminer immigration from surrounding areas. Immigration is common in the field where highly mobile adults can move from surrounding areas into experimental plots.

Three treatments were established: 1) abamectin 0.02 kg (AI)/ha in 935 liters/ha; 2) abamectin 0.02 kg (AI)/ha in 1870 liters/ha; and 3) untreated control. Abamectin treatments were applied 2 weeks after transplanting followed by weekly applications throughout the season for a total of 12 applications. Sprays were applied with a CO₂-pressurized backpack sprayer with a 6-nozzle boom at 414 kPa. Teejet 26X hollow cone nozzles were used. A surfactant, Ortho X-77 Spreader (Chevron Chemical Co., Fresno, CA) was added at 0.063% v/v to improve wetting.

Onion thrips visual damage ratings were taken weekly from 19 August to 28 October. Thrips damage was rated according to the following scale: 0 = no damage; 1 = 0–5% damage; 2 = 6–25% damage; 3 = 26–50% damage; 4 = 51–75% damage; and 5 = 76–100% damage.

Leafminer pupae were counted instead of live larvae because abamectin requires several days to kill the larvae. Pupal counts were comparable to larval counts at detecting changes in leafminer populations (Johnson et al. 1980). Pupal counts measured only leafminer larvae that survived to pupation. Plots were sampled for leafminers weekly by randomly collecting 10 onion leaves from each subplot. Samples were taken to the lab where each leaf was placed in a wax paper bag (Waxtex, 19.8 x 15.2 x 7 cm) and sealed with tape. After 4 days, leafminer pupae were counted. Cutting the leaves lengthwise to count live and parasitized larvae would have significantly shortened the period in which the onion leaves remained fresh. Therefore, live and parasitized larvae were not counted. Each plot was visually evaluated in the field for phytotoxicity on 21 August and 4 September. A 0–100% injury scale was used. Plants were harvested on 29 October. Onions were cleaned by removing damaged portions to meet Hawai'i No. 1 standards and fresh

weights were recorded.

Onion thrips ratings were analyzed by analysis of variance with single df contrast comparisons on ranked data (Rank Procedure, General Linear Models Procedure; SAS Institute 1988). Leafminer data were analyzed on a weekly basis by analysis of variance with single df contrast comparisons on ranked data because the data were not normally distributed (Rank Procedure, General Linear Models Procedure; SAS Institute 1988). Yield data were analyzed by analysis of variance with single df contrast comparisons (General Linear Models Procedure; SAS Institute 1988).

RESULTS AND DISCUSSION

1989 season

Insecticide treatments did not affect the number of live leafminer larvae per leaf (Fig. 1a) however, visual observations indicated that onions treated with abamectin at 0.02 kg(AI)/ha had less leafminer damage than the other treatments. Leafminer immigration from surrounding areas into experimental plots may have obscured treatment differences. Abamectin can take several days to kill the larvae, therefore, counts of leafminer larvae may have included larvae which subsequently died. Additionally, improved spray coverage at the outset could have further reduced leafminer counts in abamectin treated plots. Parasitized leafminer counts were not significantly different between treatments (Fig. 1b). No phytotoxicity was noted.

Green onion fresh weights (yields) from plots treated with abamectin at 0.02 kg (AI)/ha increased by 71% over the control ($F = 7.54$; $df = 1, 9$; $P = 0.0226$). Onions treated with abamectin at 0.01 kg(AI)/ha had fresh weights which were not different from the control ($F = 1.39$; $df = 1, 9$; $P = 0.2694$) (Table 1). Although counts of leafminer larvae did not decrease in abamectin treated onions, yields from plots treated with abamectin at 0.02 kg (AI)/ha were significantly greater than yields from untreated plots. If larvae in treated onions were immobilized before completing their larval stage, the total mined area in the leaf would be less when compared with untreated leaves. This could explain the higher yields in abamectin-treated plots (i.e., less leaf area removed when cleaning at harvest and more photosynthetic leaf area present).

Table 1. Green onion fresh weight for 1989 and 1991 seasons.

Season	Treatment	Mean Fresh Weight (kg/Plot)
1989	Untreated Control	2.32
	Abamectin 0.01 kg (AI)/ha	3.04
	Abamectin 0.02 kg (AI)/ha	3.99*
1991	CAGED	
	Untreated Control	5.40
	Abamectin 0.02 kg (AI)/ha	6.30
	935 liters/ha	
	Abamectin 0.02 kg (AI)/ha	5.75
	1870 liters/ha	
	UNCAGED	
	Untreated Control	3.42
	Abamectin 0.02 kg (AI)/ha	4.79*
	935 liters/ha	
	Abamectin 0.02 kg (AI)/ha	4.70*
	1870 liters/ha	

*Significantly different from untreated control plot ($P < 0.05$).

1991 season

Leafminer pupal counts were not significantly different ($F = 5.12$; $df = 1, 9$; $P = 0.05$) between treatments during the period between 5 August and 2 September in the uncaged plots except on 12 August for abamectin at 1870 l/ha ($F = 5.32$; $df = 1, 9$; $P = 0.046$) and on 26 August for abamectin at 935 liters/ha ($F = 5.88$; $df = 1, 9$; $P = 0.038$) (Fig. 2a). The nonsignificance between untreated and treated plots was due to the low leafminer densities early in the season. From 9 September to 28 October, the leafminer population increased, and numbers of leafminer pupae were less in abamectin-treated plots than in untreated plots ($F > 5.12$; $df = 1, 9$; $P < 0.05$).

Leafminer pupal counts from onion leaves in caged plots were significantly lower ($F > 5.12$; $df = 1, 9$; $P < 0.05$) in abamectin-treated plots than untreated plots on most of the sampling dates, except for the following: 26 August ($F = 3.53$; $df = 1, 9$; $P = 0.093$) and 23 September ($F = 0.64$; $df = 1, 9$; $P = 0.443$) for abamectin at 935 l/ha, and 5 August ($F = 2.22$; $df = 1, 9$; $P = 0.171$) and 23 September ($F = 2.57$; $df = 1, 9$; $P = 0.143$) for abamectin at 1870 l/ha (Fig. 2b). Caged plots had fewer leafminers overall than the uncaged plots which was probably because cages prevented immigration of leafminers from surrounding areas.

Onion thrips injury remained high throughout the season. Thrips injury ratings on onions treated with abamectin at 935 l/ha in caged ($F = 97.07$; $df = 1, 129$; $P < 0.0001$) and uncaged ($F = 55.06$; $df = 1, 129$; $P < 0.0001$) plots were lower than in the untreated control plots (Table 2). The same results were observed on onions treated with abamectin at 1870 l/ha for both caged plots ($F = 100.64$; $df = 1, 129$; $P < 0.0001$) and uncaged plots ($F = 62.14$; $df = 1, 129$; $P < 0.0001$), (Table 2). Abamectin was effective in reducing thrips injury. Spray volume did not affect efficacy against thrips. Using abamectin to control thrips would be advantageous because the use of broad spectrum insecticides for thrips control may also kill leafminer parasitoids. Because abamectin can control both thrips and leafminers without interfering with leafminer parasitoids, it is a good insecticide to use in pest management programs for green onions. No phytotoxicity was noted.

Table 2. Onion thrips visual injury ratings in caged and uncaged plots. 1991 season.

Treatment	Mean Thrips Rating	
	Caged Plots	Uncaged Plots
Untreated Control	2.79	2.82
Abamectin 0.02 kg (AI)/ha	0.75* 935 liters/ha	1.20*
Abamectin 0.02 kg (AI)/ha	0.73* 1870 liters/ha	1.11*

* Significantly different from untreated control ($P < 0.05$).

In uncaged green onions, fresh weights were 40% greater in plots treated with abamectin at 935 l/ha ($F = 10.04$; $df = 1, 9$; $P = 0.0114$) when compared with untreated plots (Table 1). Uncaged plots treated with abamectin at 1870 liters/ha had fresh weights 37% greater than untreated control plots ($F = 8.76$; $df = 1, 9$; $P = 0.0160$), (Table 1). These results support the 1989 data. However, fresh weights were not different among treatments in caged plots (abamectin, 935 l/ha: $F = 1.48$; $df = 1, 9$; $P = 0.2544$; abamectin, 1870 liters/ha: $F = 0.21$; $df = 1, 9$; $P = 0.6548$); probably because leafminer population

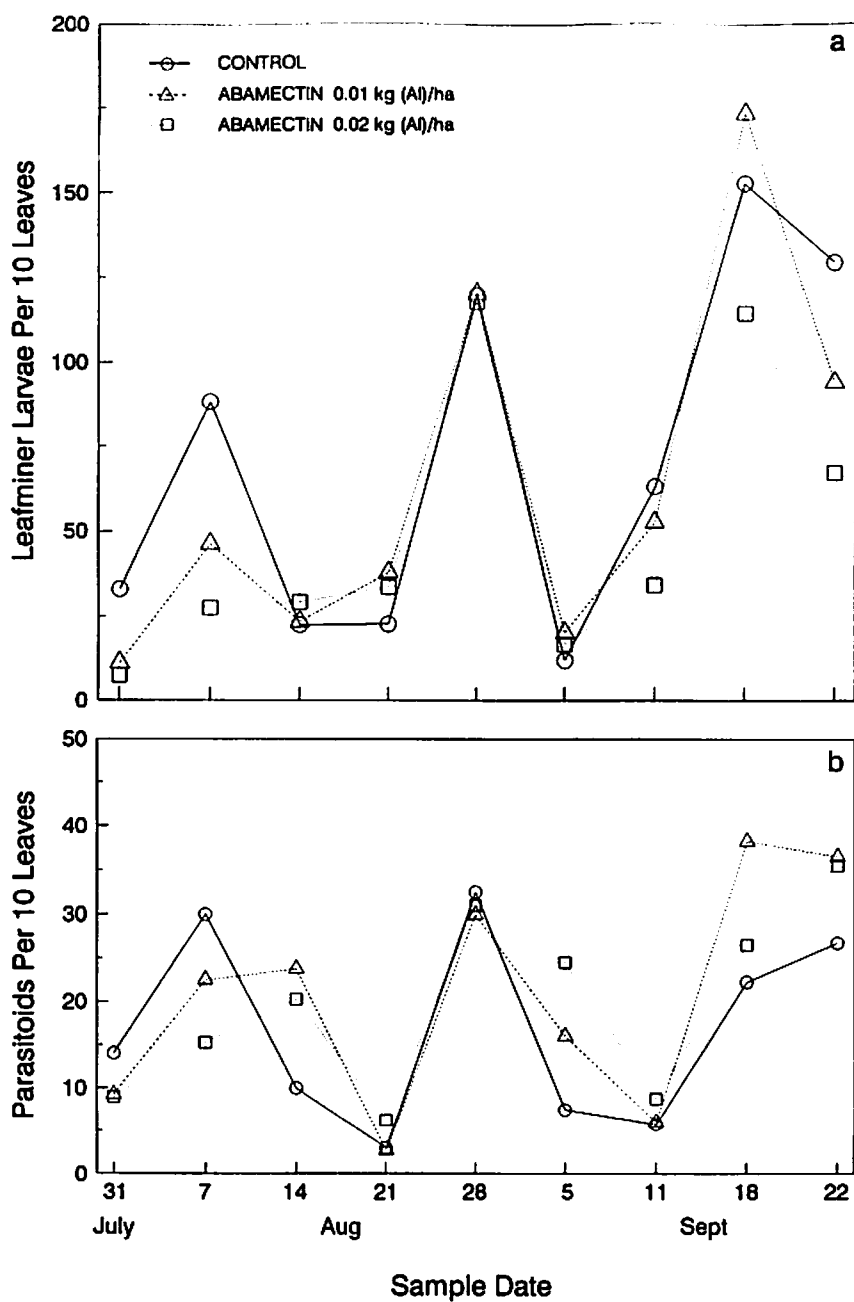


Fig. 1. Effect of abamectin on counts of live leafminer larvae and parasitized larvae over 9 weeks, 1989 season.

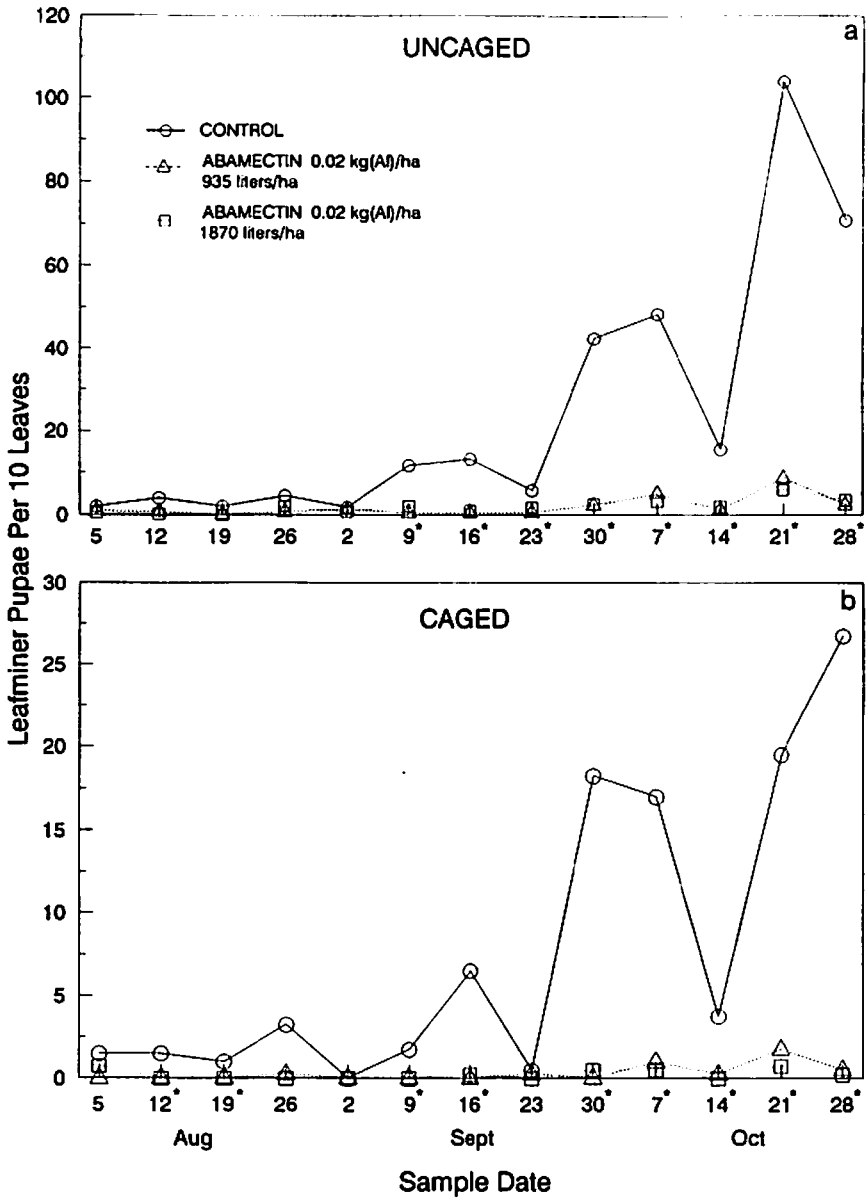


Fig. 2. Effect of abamectin on counts of leafminer pupae from leaves in caged and uncaged plots over 13 weeks. 1991 season. * = abamectin treatments significantly different ($P < 0.05$) from untreated control.

densities under the cages were relatively low early in the season and slow to increase over time. Fresh weights were greater in caged plots when compared with uncaged plots because of the marked reduction in leafminer density under the cages. Spray volume did not appear to affect green onion fresh weight or efficacy against leafminers.

Table 3. Economic analysis comparing dollar value costs of application of abamectin versus net returns in yield in green onion.

Expenditures		
Pesticide Cost¹	Labor²	Total Expenditures
\$ 3,321.00	\$ 178.56	\$ 3,499.56
Benefits		
Treatment	kg/ha Produced	Farm Value/ha³
Control	7,362.3	\$ 15,681.69
Abamectin 0.02 kg(AI)/ha	10,307.2	\$ 21,954.50
Net Benefit	2,944.9	\$ 6,272.81

1. 12 applications/ha/season at 0.02 kg(AI)/ha.

2. 1.24 hours to spray 1 ha at \$12.00/hour. (S. Fukuda, pers. comm.).

3. Hawaii Agricultural Statistics Service. 1991. Statistics of Hawaiian Agriculture, Honolulu, Hawai'i, p. 59.

An economic analysis comparing costs of abamectin application with net increase in yield is shown in Table 3. The analysis compares costs per hectare for one green onion crop cycle based on maximum use rates for abamectin; the dollar value benefits exceed the dollar value expenditures by \$2,773.25 (\$6,272.81 minus \$3,499.56). In addition to the increased crop value, growers will also benefit from the decreased labor output required for culling damaged leaves at harvest.

Green onion yields increased with abamectin treatments. Abamectin was effective in reducing onion thrips damage. The novel chemistry of abamectin diminishes the chances of resistance development, however Immaraju et al. (1992) reported abamectin resistance in western flower thrips (*F. occidentalis*). Therefore, integration of abamectin with cultural and biological controls is essential for prolonging abamectin's efficacy.

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